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Multi input DC- DC converters for hybrid renewable energy systems-an overview

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Single input DC-DC converters can be successfully replaced by a single, multiple input DC-DC converter. The structure of Multiple-Input Converter (MIC) is simpler compared to the use of several single input converters for each source. Using input renewable energy sources like photovoltaic (PV) source, wind source and fuel cell, etc, MIC can deliver power either simultaneously from all of the input sources to the load or individually. MICs reduce the system size and cost by reducing the number of components. This paper presents integrated Buck, Boost, Buck-Boost multi input DC-DC converters circuit configurations, theoretical aspects, their operational principles, merits and demerits.

Keywords: *Multi Input DC-DC converter (MIC), Integrated Buck, Boost, Buck-Boost converters.*

1.0 INTRODUCTION

In recent days, the number of applications which require more than one power source is increasing. Distributed generating systems or micro-grid systems normally use more than one source Also, to increase the utilization of renewable energy sources, a diversified energy source combination is recommended. The combination of more power sources and diversified power sources make it possible to obtain higher availability in a power system. A parallel connection of converters has been used to integrate more than one input energy source in a power system. Multi-input DC-DC converters [1-2] are playing a significant role in interfacing and diversification of different energy sources. However, as Compared to a combination of several individual converters MIC has several advantage like cost reduction, compactness, more expandability and greater manageability.

The MICs are being used in aerospace, electric and hybrid vehicles, sustainable Energy sources and micro grid applications [3]. Renewable Energy Sources (RES) [4] such as solar and wind, produce power intermittently according to the weather conditions rather than to the power demand.

2.0 DC-DC CONVERTER

A DC-DC converter is an electronic circuit that converts a DC source from one level of voltage to another [5-7]. An unregulated DC voltage is given as input to these converters and therefore it fluctuates. In these converters regulated DC output voltage is obtained although the input voltage is changing. The regulation of output voltage is based on the on-time of the switch, pulse width and the switching frequency. The control of output voltage depends on the duty cycle D. The duty ratio is defined as the ratio of the on-time of the switch and the total switching period. Duty cycle is given by the Equation 1.

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$$D = \frac{T_{on}}{T_s} \quad \text{....(1)}$$

Where,

D is the duty cycle

T_{ON} is the on period of the switch

T_S is the total time period (T_{ON} + T_{OFF})

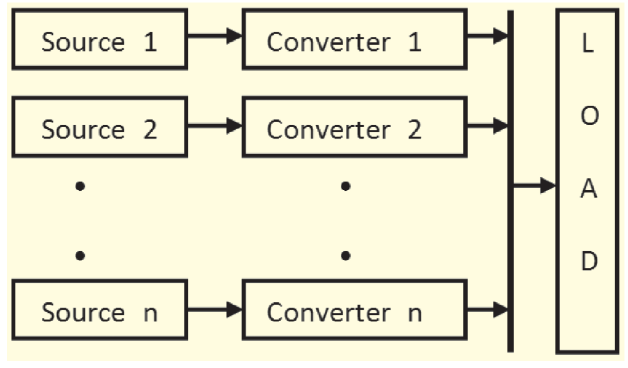

FIG. 1 CONVENTIONAL MULTI INPUT CONVERTER / SEPARATE CONVERTERS FOR EACH SOURCE

3.0 MULTI INPUT DC-DC CONVERTERS

Multiple-Input DC-DC converters are an unique solution to combine several input power sources whose voltage levels and/or power capacity are different and to get regulated output voltage [8-11] .

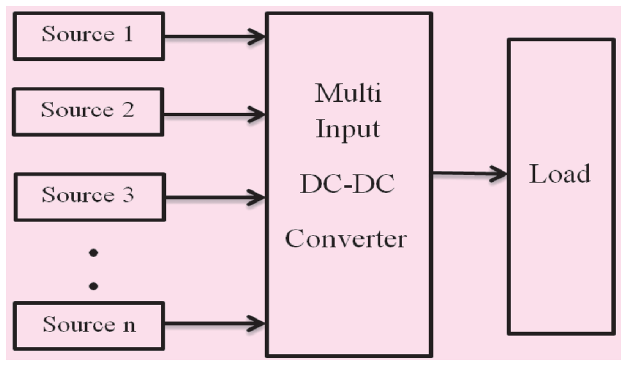

FIG. 2 A MULTI INPUT DC/DC CONVERTER

Three basic types of integrated multi input DC-DC converters are widely presented by detail Lalit Kumar et. al [3].

They are

a) Integrated Buck/Buck converter

b) Integrated Buck/Buck-Boost converter

c) Integrated Buck-Boost/Buck-Boost converter

Here each of the above converters has two input sources.

3.1 Integrated Buck/Buck converter

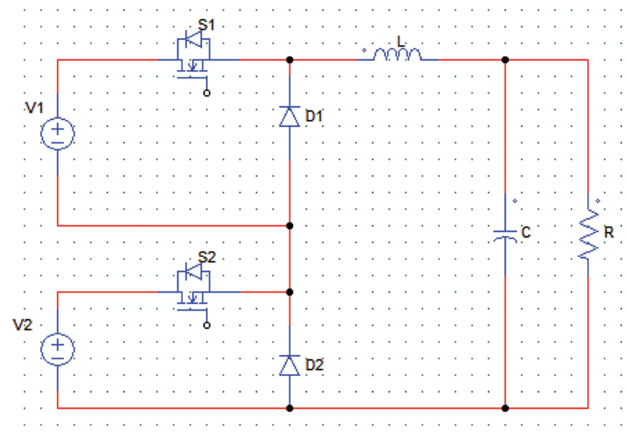

FIG. 3 INTEGRATED BUCK-BUCK CONVERTER

The Integrated Buck/Buck converter is presented in Figure 3.

State I (S_1=ON, S_2 =OFF):

When S_1 ON, D_1 is reverse biased, D_2 provides a bypass path for inductor current, Source 1 provides the energy to the inductor and load.

State II (S_1=OFF, S_2 =ON):

In this condition S_2 is ON, D_2 is reverse biased, D_1 provides a bypass path for inductor current, Source 2 provides the energy to the inductor and load.

State III (S_1=OFF, S_2 =OFF):

In this condition S_1 and S_2 are OFF, D_1& D_2 provides a current path for the inductor current, The Stored energy in the inductor supplies to load.

State IV (S_1=ON, S_2 =ON):

In this condition $S_1$and S_2 both are ON and both D_1, D_2 is reverse biased. A source 1& 2 are connected in series and provides the energy to the inductor and load.

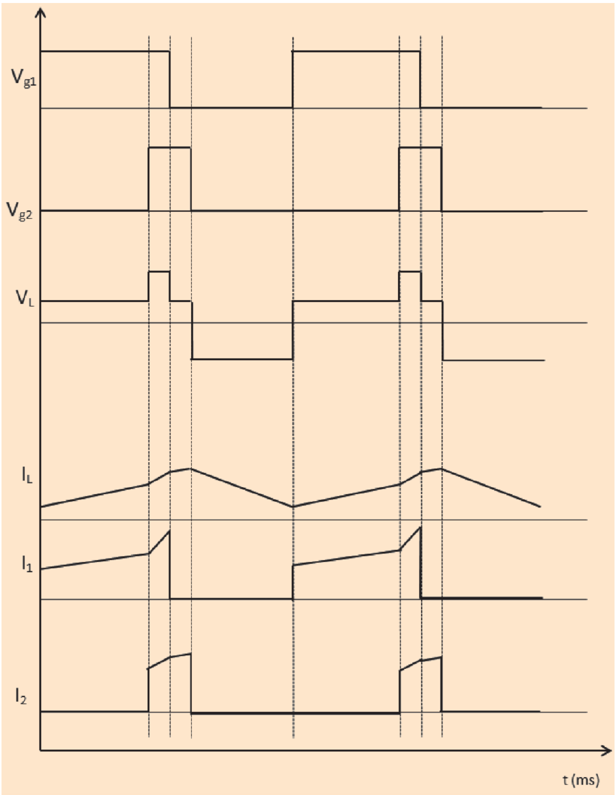

FIG. 4 TYPICAL WAVEFORMS OF INTEGRATED BUCK-BUCK CONVERTER

The output voltage V_o is given by (applying volt-second balance theorem)

$$V_0 = V_1 D_1 + V_2 D_2 \quad ....(2)$$

The typical waveforms of the converter, gate signals of switches S_1& S_2 (V_{g1}, V_{g2}), voltage across the inductor (V_L), current through the inductor (I_L), both source input currents (I_1, I_2).

3.2 Integrated Buck/Buck-Boost converter

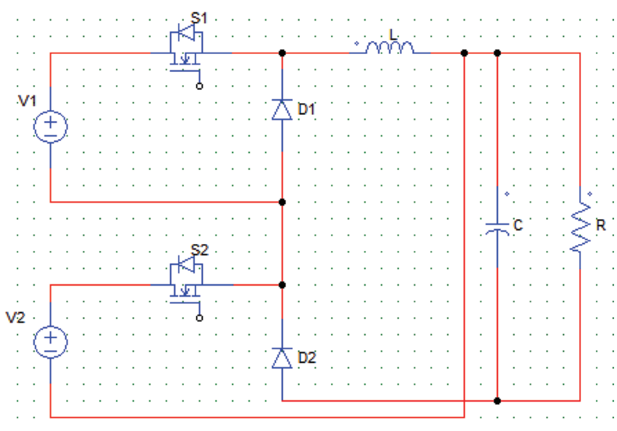

FIG. 5 INTEGRATED BUCK/BUCK-BOOST CONVERTER

The Integrated Buck/Buck-Boost converter is shown in Figure 5. The operating principle is described below.

State I (S_1=ON, S_2 =OFF):

In this state Source 1 powers the load through the inductor.

State II (S_1=OFF, S_2 =ON):

Source 2 provides the energy to the inductor and load.

State III (S_1=OFF, S_2 =OFF):

Both switches are OFF, the stored energy in the inductor and capacitor supplies to load.

State IV (S_1=ON, S_2 =ON):

Both switches are ON, both sources are working simultaneously and charging inductor and supplies to load.

The output voltage V_o is given by (applying volt-second balance theorem)

$$V_0 = \frac{D_1}{1-D_2} V_1 + \frac{D_2}{1-D_2} V_2 \quad ....(3)$$

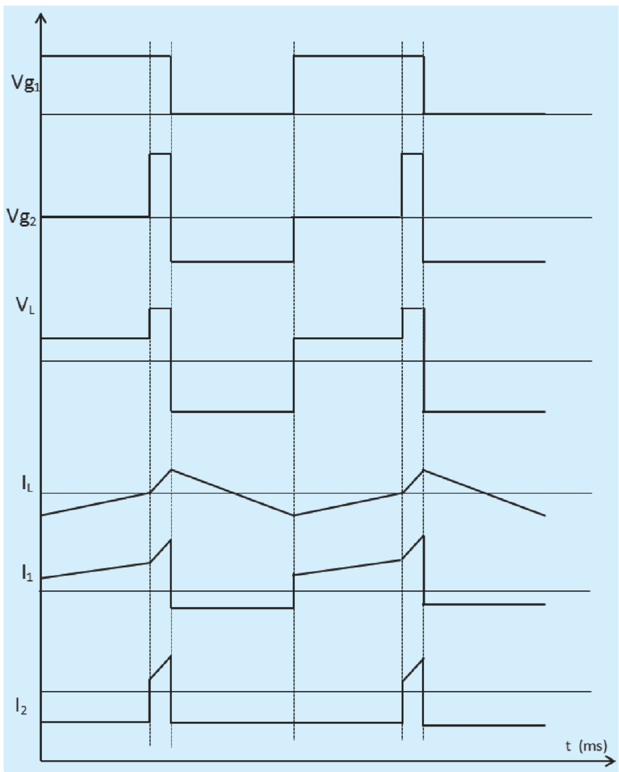

FIG. 6 TYPICAL WAVEFORMS OF INTEGRATED BUCK/BUCK-BOOST CONVERTER

The typical waveforms of the converter, gate signals of switches S_1 & S_2 (V_{g1}, V_{g2}), voltage across the inductor (V_L), current through the inductor (I_L), both source input currents (I_1, I_2).

3.3 Integrated Buck-Boost/Buck-Boost converter

The Integrated Buck-Boost/Buck-Boost converter is presented in Figure 7. The operating principle is as follows:

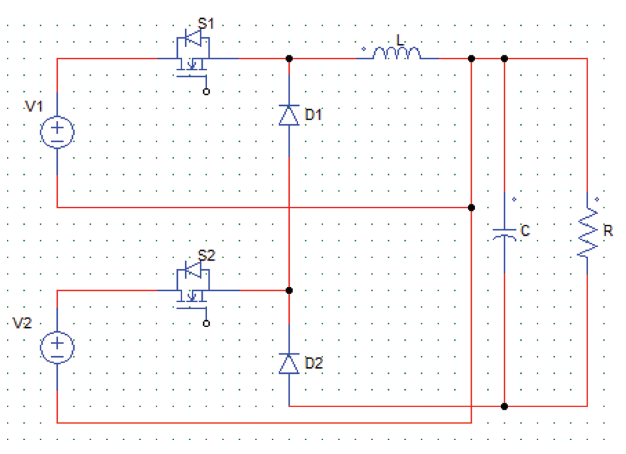

FIG. 7 INTEGRATED BUCK-BOOST/BUCK-BOOST CONVERTER

This converter works in three states.

State I (S_1=ON, S_2 =OFF):

In this state Source 1 powers the load through the inductor.

State II (S_1=OFF, S_2 =ON):

Source 2 provides the energy to the inductor and load.

State III (S_1=OFF, S_2 =OFF):

Both switches are OFF, the stored energy in the inductor and capacitor supplies to load.

The output voltage V_o is given by

$$V_0 = \frac{D_1}{1-D_1-D_2}V_1 + \frac{D_2}{1-D_1-D_2}V_2 \quad \text{....(4)}$$

The typical waveforms of the converter, gate signals of switches S_1& S_2 (V_{g1}, V_{g2}), the voltage across the inductor (V_L), current through the inductor (I_L), both source input currents (I_1, I_2) are shown in Figure 8.

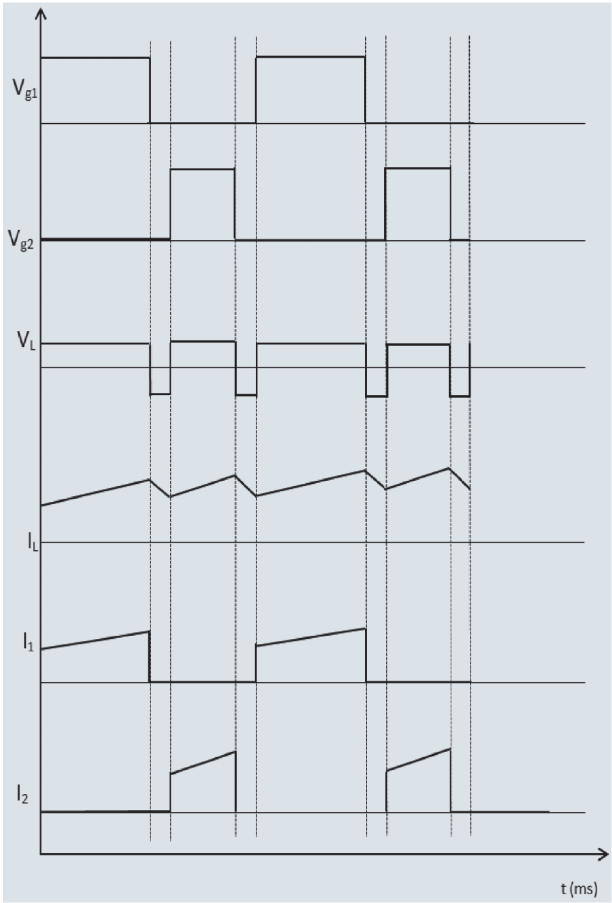

FIG. 8 TYPICAL WAVEFORMS OF INTEGRATED BUCK-BOOST/BUCK-BOOST CONVERTER

4.0 COMPARISON OF MULTI INPUT DC-DC CONVERTER TOPOLOGIES [1-17]

Topology	Cost	Reliability	Efficiency
MI Buck	**	**	***
MI Boost	***	**	****
MI Buck-Boost	*	*	*

"*" sign shows the attribute of topology i.e. "***" is better than "**" which is better than "*".

4.1 Limitations [1-17]

i. Complex control system

ii. No energy storage system

5.0 CONCLUSIONS

In this review paper Multi input DC-DC converters are presenetd in detail. The different topologies are explained for Hybrid renewable energy systems. Limitations are brought out very clearly. Finally, these converters are

i. Less power electronic components.

ii. Single stage conversion

iii. More reliable

iv. Continuous power flow to the load even if any one source also damaged.

v. AC or DC Nano grid applications.

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